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ABSTRACT

This study, part of the Colorado Science Meta-Analysis Project, was designed to assess the effectiveness of teacher education programs on preservice and inservice teachers having as measured outcomes one or more variables associated with inquiry teaching. Inquiry teaching within the context of the study addresses teacher behaviors facilitating student acquisition of concepts, processes, and skills through active involvement with general inquiry strategies. Specific outcome criteria which appeared in the research reviewed for the analysis and judged as falling within the confines of this definition include: knowledge of science processes, inquiry instructional strategy, indirect verbal behavior, accepting interpersonal behaviors, increased wait-time questioning behavior, higher cognitive questioning behavior, and discovery instructional strategy. Sixty-eight studies, involving at least one of these outcomes associated with inquiry strategy, were selected for analysis. Relevant variables (114) were identified and coded according to: study form/design characteristics, teacher/teacher trainee characteristics, student characteristics, treatment characteristics, outcome characteristics, and effect size calculation characteristics. Because descriptive reporting of teacher and/or student characteristics which might affect outcome measures was sporadic and occurred with frequencies too low to support analysis, the analysis was divided into categories focusing on variables associated with: methodological aspects of studies, study treatments, and the variety of teacher education outcomes sought. (JN)

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by

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A META-ANALYSIS OF RESEARCH ON SCIENCE TEACHER EDUCATION PRACTICES ASSOCIATED WITH INQUIRY STRATEGY

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TABLE OF CONTENTS

INTRODUCTION iii

LITERATURE SEARCH AND SELECTION OF STUDIES 1

SELECTION OF STUDIES, CODING OF VARIABLES, AND EFFECT SIZE CALCULATIONS 1

ANALYSIS OF DATA 2

Teacher Outcomes - Methodological Variables. 3

Summary. 9

Teacher Outcomes - Treatment Variables 9

Summary. 16

Teacher Outcomes - by Outcome Category 16

Summary. 17

BIBLIOGRAPHY I - Coded Studies 19

BIBLIOGRAPHY II - General References 25

LIST OF TABLES

TABLE I - Teacher Outcome Effect Sizes Across Study Methodological Variables. 4

TABLE II - Correlations Among Selected Methodological Variables and Between Methodological Variables and Effect Size 5

TABLE III - Teacher Outcome Effect Sizes Across Effect Size Calculation Variables. 8

TALBE IV - Teacher Outcome Effect Sizes Across Treatment Variables (Part I) 10

TABLE V - Teacher Outcome Effect Sizes Across Treatment Variable (Part II). 12

TABLE VI - Correlations Between Selected Treatment Variables and Effect Size. 13

TABLE VII - Teacher Outcome Effect Sizes by Type of Outcome. 14

INTRODUCTION

This meta-analysis study was a part of the Colorado Science Meta-Analysis Project (Anderson, 1982) designed to provide a synthesis of research related to science education on a number of important questions related to the teaching and learning of science and the preparation of teachers of science.

One of the important science education concerns has been the effects of different preservice and inservice science teacher education approaches on teachers and, ultimately, the effects of teachers on their students. During the 1960's and 1970's several of the curriculum projects developed materials designed to be taught in an inquiry style that was investigative and student centered; inquiry skills were also desired outcomes of instruction. This study was designed to assess the effectiveness of teacher education programs on preservice and inservice teachers having as measured outcomes one or more variables associated with inquiry teaching.

Inquiry teaching within the context of this paper addresses those teacher behaviors that facilitate student acquisition of concepts, processes, and skills through active involvement with general inquiry strategies. It incorporates aspects of the investigative and discovery phases of science and affords opportunities for the students to test and refine concept meanings. Through this type of learning, and the acquisition and synthesis of scientific knowledge and processes, the ability to perform scientific inquiry becomes possible. A teacher equipped to engage in inquiry teaching would possess questioning skills that are divergent, have a knowledge of science processes and have the capacity to conduct student-centered inductive learning activities. Specific outcome criteria which appeared in the research reviewed for this analysis and judged as falling within the confines of this definition include the following: knowledge of science processes, inquiry instructional strategy, indirect verbal behavior, accepting interpersonal behaviors, increased wait-time questioning behavior, higher cognitive level questioning behavior, and discovery instructional strategy. This meta-analysis was limited to studies involving at least one of these outcomes associated with inquiry strategy.

LITERATURE SEARCH AND SELECTION OF STUDIES

Because this meta-analysis was focused upon inquiry teaching, research dated between 1965 and 1980 was considered. This period parallels the implementation period for the modern science curriculum projects.

A second limitation was suggested by the work of Munby (1980). He concluded that "on the basis of this analysis there are grounds for viewing research on the affective outcomes of science education with misgiving, simply because there seems little to be said of the instruments as to enlist our confidence in their use." Furthermore, if we are attempting to change attitudes with an eye toward teacher practice, a review of research on changing the attitude of student teachers by Morrisey (1981) is relevant. He claimed that the lack of change in the teaching of elementary school science indicates something more than just immediate attitude change must be considered. Therefore, studies involving only affective outcomes were not included in this meta-analysis.

The literature search process began with disserations. Dissertations listed in the Science Education Dissertation Bibliography (1978) were identified.

Journal articles were identified applying the same criteria as for dissertations by scanning the table of contents of the Journal of Research in Science Teaching and Science Education for the years 1965 to 1980. Research from sources other than dissertations and journals was identified through a search of the three ERIC compilations of abstracts from Resources in Education (1966-1972, 1973-1975, 1976-1977) and Resources in Education for later years. In addition, NARST Annual Reviews of Research and NARST Abstracts for many years were reviewed to identify potential studies.

A number of studies identified were rejected for the following reasons: (1) data needed for the calculation of effect size were incomplete, (2) measured outcomes were only in the affective domain, (3) the native language of the subjects was other than English, (4) the study was produced prior to 1965, or (5) the outcome variables were not associated with inquiry teaching strategy.

SELECTION OF STUDIES, CODING OF VARIABLES, AND EFFECT SIZE CALCULATIONS

Sixty-eight studies were selected for analysis. Relevant variables were identified and coded according to the following six major categories: study form and design characteristics, teacher/teacher trainee characteristics, student characteristics, treatment characteristics, outcome characteristics, and effect size calculation characteristics. These categories and six variables for the management of the data deck resulted in the delineation of 114 variables.

Effect size calculations were performed using the most straight forward method possible with the data presented in each study. The most straight-forward method available and the one used in 64% of the effect size calculations involved standardization of the mean differences between treatment and control groups.

ANALYSIS OF DATA

The 68 studies were coded; these resulted in 177 effect size calculations. Outcomes were measured on teachers, on students, and on students about teachers. While many researchers advocate measuring teacher behavior by evaluating student performance, this practice occurred in a very small number of cases. One hundred and fifty-four effect sizes were outcomes measured on teachers, while only nineteen were outcomes measured on students and four were student measures about teachers. Because of the small sample size, no analysis of the effect sizes related to outcomes measured on teachers by students was performed.

While many science educators advocate measuring teacher performance by measuring student outcomes, this practice occurred infrequently in this collection of studies on science teacher education. The nineteen effect sizes related to outcomes measured on students produced a mean effect size of .44 and a standard deviation of .67 when broken down across all variables. The mean reliability of the measurement instruments was .82 with a standard deviation of .06. The outcome most frequently measured (47% of the cases) was the knowledge of science processes.

The one hundred and fifty-four effect sizes related to outcomes on teachers produced a mean effect size of .85 with a standard deviation of 1.30 when broken down across all variables. One effect size determination was considered a far outlier, having a value three time greater than the next closest effect size and being approximately ten standard deviations above the mean. If this value is discarded, the mean effect size across all variables becomes .77 with a standard deviation of .86.

The size of the teacher samples ranged from 9 to 299, with a mean of 60.4 and a standard deviation of 45.2. The number of teachers assigned to each treatment ranged from 5 to 129, with a mean of 26.8 and a standard deviation of 17.6. Test reliability was reported for 50 percent of the outcome measurement instruments, yielding a mean of .81 and a standard deviation of .09. Duration of treatment (with seven missing cases) ranged from less than a day to one year. The mean was 70.0 days with a standard deviation of 71.4.

Descriptive reporting of teacher and/or student characteristics which might affect outcome measures was sporadic and occurred with frequencies too low to support analysis. Therefore the analysis was divided into the following

three major categories: (a) variables associated with methodological aspects of the studies, (b) variables associated with study treatments, and (c) variables associated with the variety of teacher education outcomes sought.

Teacher Outcomes - Methodological Variables

Table I presents the means, standard deviations, and sample sizes of selected methodological variables broken down across outcomes measured on teachers. Table II presents the Pearson correlation coefficients and significance level between selected methodological variables and between selected methodological variables and effect size. In situations where the variable categories did not reflect an ordinal relationship the categories were coded dichotomously for correlational purposes.

Table I presents nine methodological variables with the categories that had sufficient sample size to warrant discussion. The form of publication variable indicates that the source of the information used for coding purposes. An attempt was made to locate the primary source whenever possible and if a study was presented as both a journal article and a dissertation, the dissertation was used as the source. The mean effect size calculated from journal articles was 1.01 while those calculated from dissertations was .59. There was significant positive correlation ($p=0.0004$) between journals as a source and effect size and a significant negative correlation ($p=0.05$) between dissertations as a source and effect size. These results indicate that a meta-analysis based solely on journals as a source has the potential of establishing effect size data higher than what might be expected if the extensive dissertation literature were used also.

The type of study variable was coded using the guidelines established by Campbell and Stanley (1963). Pre-experimental designs consisted of one-group pretest-posttest designs and static-groups comparison designs. Experimental designs involved pretest-posttest control groups designs and posttest-only control group designs with random assignment of subjects to treatment and control groups. Quasi-experimental designs involved the same designs as the experimental groups, but without random assignment of subjects. The mean effect size ranged from .90 for pre-experimental to .67 for experimental studies. The correlation coefficient was not significant at the .05 level.

The assignment of teachers to treatments was coded as random, matched, self-selected, intact groups, representative sample, and other. Random assignment and intact group assignment together accounted for 76% of the effect sizes produced. Random assignment studies had an average effect size of .67 and intact groups produced an effect size mean of .88.

The teacher unit of analysis variable indicated the unit (individual or group) that was used in establishing the degrees of freedom for the determination of significance level. The teacher unit of analysis used the number of individuals involved to determine degrees of freedom in 95% of the cases.

Table I
Teacher Outcome Effect Sizes
Across Study Methodological Variables

Variable	Mean Effect Size	Standard Deviation	N
Form of publication			
Journal	1.01	.98	61
Dissertation	.59	.77	85
Other	.75	.24	7
Type of study			
Pre-experimental	.90	.73	22
Quasi-experimental	.78	.83	69
Experimental	.67	.92	60
Assignment of teachers to treatments			
Random	.67	.91	61
Self-selected	.57	.78	17
Intact groups	.88	.86	56
Teacher unit of analysis			
Individual	.77	.88	145
Classroom or group	.75	1.00	4
Rated internal validity			
Low	.55	.55	25
Medium	.75	.82	55
High	.82	.98	68
Design Rating			
Low	.57	.80	41
Medium	.68	.61	38
High	.92	.99	72
Outcome instrument type			
Published, national stand.	.35	.58	16
Ad hoc, for that study	1.12	.94	59
Other	.60	.76	77
Measurement method			
Multiple choice	.48	.61	31
Likert	.50	.44	24
Observation	.24	.93	49
Other	1.14	1.07	35
Time of measurement			
After treatment	.62	.76	80
Pre-post	.90	.96	80
Other	.74	.59	9

Table II

Correlations Among Selected Methodological Variables and Between Methodological Variables and Effect Size

Variable A	Variable B	r	p	N
Form of pub. journal	effect size	0.23	0.004	61
Form of pub. journal	extent of treat	0.21	0.008	61
Form of pub. journal	# of teachers assigned	-0.04	0.634	61
Form of pub. journal	# of teachers analyzed	-0.00	0.959	61
Form of pub. journal	reported sig.	-0.22	0.010	61
Type of study	effect size	-0.09	0.248	151
Rated internal validity	effect size	0.10	0.214	148
Design rating	effect size	0.17	0.035	151
Outcome instrument, pub. national standardized	effect size	-0.17	0.039	16
Outcome instrument. ad hoc	effect size	0.32	0.000	59
Outcome instru. other	effect size	-0.20	0.012	77
Measurement method multiple choice	effect size	-0.17	0.039	31
Measurement method other	effect size	0.24	0.003	35
# of teachers assigned	effect size	-0.21	0.011	152
# of teachers analyzed	effect size	-0.17	0.031	153
# of teachers on outcome measure	effect size	-0.17	0.035	149

An internal validity variable addressed the assignment of individuals to treatments, and the percent mortality among treatment and control groups. Studies were rated high in internal validity if group equivalence was established through random assignment or other procedures and subject mortality was less than 15 percent. Studies were coded as medium if (a) randomization was not used but low mortality was maintained, (b) randomization existed but mortality was high or nonequivalent, and (c) if random procedures were used in the selection of intact groups and mortality was low. Studies were coded as low where intact convenience samples were used and/or where the existence of factors confounding the equivalence of the subject groups was apparent. Studies rated low in validity produced effect sizes with a mean of .55, medium validity studies produced effect sizes with a mean of .75, and high validity studies produced effect sizes with a mean of .82. The internal validity was positively correlated with effect size, but was not significant at the .05 level.

The design rating variable addressed the apparent degree of control of the confounding variables by the experimental procedure. Studies were rated as high if the design established control to the extent that post-treatment differences could be attributed to treatment effects. The study was rated as medium if the design indicated lack of control of a variable that probably contributed to some outcome differences. The study was rated as low if the failure to control a given variable obviously contributed to outcome differences. Studies with a low design rating had an average effect size of .80, medium studies had an average effect size of .61, and high studies had an average effect size of .99. A positive correlation coefficient with a significance level of .035 indicated that larger effect sizes were associated with higher design ratings.

A variable, outcome instrument type, included instruments categorized as (a) published, (b) ad hoc developed for that particular study, or (c) other. Most of the tests in the "other" category were developed ad hoc for another study and then used in existing form or with modifications for the study being coded. The effect sizes that resulted from ad hoc instruments produced a mean effect size of 1.12. Other instruments produced an effect size of .60 and published instruments a mean of .35. The ad hoc instruments had a significant positive correlation with effect size ($p > 0.001$) and the published and other categories had a significant negative correlation with effect size ($p > .05$). While these notable higher effect sizes for the specially designed instruments could be due to investigator bias, it seems more likely the result of the instruments being better designed to detect outcome differences to which the given study is directed.

Measurement method categories produced the following results for mean effect size: multiple choice .48, Likert .50, observation .84, and other 1.14. Multiple choice methods correlated negatively with effect size with a significance of .039. The "other" category correlated positively with effect size with a significance of .003. The remaining categories did not correlate significantly at the .05 level.

The time of measurement variable included the following categories: (a) after treatment, (b) pre-post, and (c) other. The latter category was used when different instruments on the same outcome were averaged to determine one effect size. The pre-post measurement produced the largest mean effect size, .90. The "other" category had a mean effect size of .74 and the after treatment category .62.

The number of teachers assigned to the study, the total number analyzed, and the number measured on each outcome instrument correlate negatively with effect size (significant at level of $p > .05$). The journal category of the form of publication variable did not correlate significantly at the .05 level with any of the variables related to sample size, but the journal category did correlate significantly with the reported significance variable and the extent of treatment variable. The extent of treatment variable addressed the scope of the treatment with a multi-grade treatment, a program, or an on-going institute being at the broad end of the scale and a specific training technique being at the narrow end of the scale. These correlations indicated that studies taken from journals had low values for p and that these studies addressed treatment types of narrow scope.

Table III presents the average effect size, standard deviations and correlation coefficients for two of the variables related to effect size calculations: (a) source of means i.e., unadjusted posttest, pre-post difference or other and (b) method for calculation. Means for the calculation of effect size were unadjusted post-test means in 83 cases and provided a mean effect size of .62 with a standard deviation of .74. Means were a result of pre-post differences in 47 cases with a mean effect size of 1.00 and a standard deviation of 1.09. The "other" category involved pre-experimental studies wherein pre-test data were used to generate a control group mean. This category provided a mean effect size of .88 and a standard deviation of .75. The unadjusted post-test source of means had a negative correlation with effect size significant at the .05 level. The source of means in the pre-post category had a positive correlation with effect size significant at the .05 level also.

The methods used for calculating the effect size included the following: (a) calculating directly from reported means and variances or from raw data, (b) calculating with direct estimates of the variance from ANOVA, t, and F values, (c) calculating using reported probability levels, and (d) calculating using pre-test data as a control group. Using pre-test data as a control group produced the highest mean effect size, 1.01 with a standard deviation of .78. The means and standard deviations for using directly reported means and variances and direct estimates were close, having mean effect values of .72 and .84 respectively. None of the calculation method variables showed a significant correlation with effect size at the .05 level.

Table III

Teacher Outcome Effect Sizes
Across Effect Size Calculation Variables

Variable	Mean Effect Size	Standard Deviation	N
Source of means unadjusted post-test	.62	.74	83
Source of means pre-post differences	1.00	1.09	47
Source of means other	.88	.75	19
Calculated directly from reported values or raw data	.72	.90	96
Calculated with direct estimates (ANOVA, t, F)	.84	.87	34
Calcuated from reported probability levels	.71	.15	5
Calculated using pre-test data as a control group	1.02	.78	15

Correlation with Effect Size

Variable	r	p	N
Source of means unadjusted post-test	-0.1865	0.021	83
Source of means pre-post dif.	0.1745	0.031	19
Calculated directly from reported values or raw data	-0.0694	0.394	96
Calculated with direct estimates (ANOVA, t, F)	0.0420	0.606	34
Calculated from reported probability levels	-0.0131	0.872	5
Calculated using pre-test data as a control group	0.0948	0.244	15

Summary

Many methodological variables were correlated with effect sizes. Nearly all the results of the correlations agree with the general findings of the other meta analysis studies when these variables were analyzed (Anderson, 1982). Methodological variables correlating positively with effect size at the .05 level (or higher) of significance were (1) studies published in journals, (2) better research designs, (3) the use of specially designed instruments (rather than standardized, nationally used instruments), and (4) studies involving smaller numbers of teachers. High internal validity correlated positively but was not significant at the .05 level.

These results indicate that the design of the study, the sample size (or the intensity of the instruction), and the appropriateness of the instrument for the outcomes being measured all relate to the level of the effect sizes in a significant way. The relationships found in this meta-analysis and in other meta-analysis studies provide guidance for designing effective instruction. Some cautions are suggested in interpreting non-significant results in research that have not considered these relationships; the non-significant finding may not be due to the instruction, but rather to the problem of sample size (or intensity of instruction) and inappropriate instruments. Careful analysis of non-significant studies may provide clues for studies that might give significant results with better instrumentation and more attention to sample size and intensity of instruction.

The correlations of sample size to effect size help to explain why some effective research results are hard to implement effectively with larger samples of teachers. Providing adequate instruction, getting teachers to follow guidelines, and providing feedback for a large sample is much more difficult than working with a small sample.

The significant correlation of journal articles with effect size presents a caution to people doing secondary analysis of research. The primary literature usually contains more non-significant studies and studies with smaller effect sizes. While these additional studies from the primary literature may not change the conclusions in all meta-analysis studies, the differences encountered in some studies such as this one indicate that there is a good possibility that different conclusions might result without the use of primary literature data.

Teacher Outcomes - Treatment Variables

Tables IV and V present the effect sizes of teacher outcomes broken down across various treatment variables. Table VI presents correlations between treatment variables and effect size. The first of these variables, time of treatment, was categorized as pre-service and in-service. These two groups produced mean effect sizes of .78 and .72 respectively.

Table IV

Teacher Outcome Effect Sizes
Across Treatment Variables (Part I)

Variable	Mean Effect Size	Standard Deviation	N
Time of treatment			
Pre-service	.78	.90	122
In-service	.72	.74	31
Site of treatment			
Field-based, site of employment	.74	.86	5
Field-based, not the site of employment	.77	.60	20
University-based	.77	.88	112
Extent of treatment			
Multi-grade or level, e.g., program or ongoing institute	.45	.45	12
One grade level, e.g., course or workshop	.75	.78	69
Training technique	.84	.98	72
Treatment geared to grade level			
Elementary school	.76	.86	123
Secondary	.39	.32	8
General	1.24	.97	15
Number of variables used to describe each treatment			
1	.67	.57	42
2	.65	.89	64
3	.73	.62	31
4	1.25	1.03	14

The site of treatment variable categorized field-based treatments versus university based treatments. The field-based treatments category was further divided into treatments that ocurred in the schools in which the teachers were employed versus treatments in schools where the individuals were not employed. Treatments were predominately university-based, accounting for 77% of the reported effect sizes. The mean effect sizes for the three groups were very close in value ranging from .74 to .77.

The extent of treatment variable ranged from a broad scope addressing multi-grade or program treatments to treatments that focused on a particular training technique. The multi-grade or program level produced a mean effect size of .45, the one grade or level variable produced a mean effect size of .75, and the training technique level produced a mean effect size of .84.

The "treatment geared to grade level" variable categorized the target population where the treatment outcomes were to be applied. The elementary level group accounted for 81% of the effect sizes coded and produced a mean effect size of .76 with a standard deviation of .86. Those treatments categorized as secondary had a mean effect size of .39 and those categorized as general had a value of 1.24.

In many instances more than one treatment variable was used to classify a treatment. Those treatments that were described using one variable produced a mean effect size of .67; two variables, .89; three variables, .73; and four variables, 1.25. A positive correlation between this variable and effect size occurred at a probability level $p > .001$.

Of the many treatment variables, those designated here as "treatment type" are of particular interest. The data on these variables is found in Table V; this Table, in contrast to the previous Tables, includes all variables regardless of the number of effect sizes recorded.

Treatment type variables were divided into the following sections: organizational pattern, type of instruction, mode of instruction, source of structure, locus of control, training techniques and technology employed. The first of these categories refers to the form of organizational pattern within which the instruction was offered. The next five all refer to the type of instruction offered.

Some treatments were categorized in terms of the treatment organizational pattern and included the following: field-based programs, workshops, methods courses, science courses designed for teachers, and units of study. Those variables with an N of more than three included the field-based program category with a mean effect size of .35, the workshop level at .73, methods courses at .79, science courses designed for teachers at .97, and specific units of study at 1.38. The type of instruction category pertains to the instructional approach used in the teacher education activities. If the treatment involved instruction versus no instruction with no further delineation of approach, it was categorized as general. Other approaches

Table V

Teacher Outcome Effect Sizes Across Treatment Variable (Part II)

Treatment Type			s	n
Organizational Pattern	Field-based Program	.35	.40	8
	Ongoing Institute	.64	.48	2
	Summer Institute	.14	.09	3
	Workshop	.73	.75	16
	Methods Course	.79	.94	22
	Science Course	1.28	.48	2
	Science Course Designed for Teachers	.97	.70	9
	Units of Study	1.38	1.29	22
Type of Instruction	General	.79	1.21	35
	Traditional	.30	.32	5
	Inquiry	.63	.63	9
	Discovery	.40	.29	7
Mode of Instruction	Verbal	-.03	.18	2
	Mixed	.45	.86	12
	Concrete	.75	.75	20
Source of Structure	Student Self-Directed	.04	.46	8
	Student Interacting with Teacher and/or Materials	.70	1.01	8
	Teacher	--	--	0
	Criterion referenced	.69	.02	2
Locus of Control	Student self-directed	.82	.88	44
	Teacher directed	1.44	0	1
	Mix, part student, part teacher	--	--	0
Training Technique	Interaction Analysis Feedback	1.33	0	1
	Instructional Strategy Feedback	.67	.91	10
	Wait-Time Analysis	3.95	.07	2
	Questioning Analysis	1.38	1.65	8
	Micro-teaching Peers	.72	.35	4
	Micro-teaching Students	.81	.52	6
	Modeling Strategy	1.56	1.19	14
	Behavior Coding Training (e.g. IA) or Strategy Analysis	1.37	.87	8
Technology Employed	Audio Technology	1.04	.25	4
	Video Technology	1.82	1.44	9
	Programmed Material (Audio-Tutorial)	.99	.76	17
	Print Material	1.40	0	1

Table VI

Correlations between Selected Treatment Variables and Effect Size

Variable	r	p	N
# of variables describing treatment	0.3123	0.000	153
treatment units of study	0.2884	0.000	22
source of structure student self-directed	-0.2003	0.013	8
questioning analysis	0.1664	0.040	8
modeling strategy	0.2928	0.000	14
behavior coding training or strategy analysis	0.1[illegible]	0.043	8
video technology	0.303[illegible]	0.000	9
outcome science processes	0.1871	0.021	33
outcome questions process directed	0.1962	0.015	9

Table VII

Teacher Outcome Effect Sizes by Type of Outcome

Type of Outcome			s	n
Knowledge and Intellectual Processes	Science Content	.52	.79	7
	Science Processes	1.08	1.03	33
	Methods of Science and the Scientific Enterprise	.14	.74	3
	Critical Thinking	.09	0	1
	Creativity	.19	0	1
	Problem Solving	.04	.23	5
	Behavioral Objectives	.75	.14	3
	Planning (organizational skill)	.90	.12	2
	Composite Knowledge and Intellect	.80		55
Teacher Classroom Behavior	Verbal Behavior, General	.15	0	1
	Inquiry Strategy	.89	.47	4
	Concrete Manipulative Strategy	1.26	0	1
	Indirect Verbal Behavior	.72	.82	18
	Interpersonal Behaviors	.54	.26	5
	Questioning-level	.72	1.18	13
	Discovery Strategy (Student Centered, Open)	.70	.53	7
	Group Process Skills	.26	0	1
	Question - Process Directed	1.45	.60	9
	Reactions to Classroom Situations	.84	0	1
	Composite Teacher Classroom Behaviors	.82		60
Affective	Attitude (general)	.79	.56	6
	Attitude toward Science	.39	.29	10
	Attitude toward Science Teaching	.09	.21	4
	Attitude toward Treatment	.46	0	1
	Dogmatism (toward open)	.34	.34	5
	Philosophy of Teaching (toward student centered)	.72	.65	4
	Attitude toward Treatment Emphasis	.60	0	1
	Composite Affective	.47		31

were termed traditional, inquiry, and discovery. The classification as inquiry or discovery was made from the language used in the study coded even though the terms were considered as synonymous in this report. The general instructional category produced a mean effect size of .79, traditional instruction had an effect size of .30, the inquiry category had a mean effect size of .63, and the discovery approach had an N of .40.

The mode of instruction categorized the approaches as predominately verbal, predominately concrete, indicating a high level of student involvement with manipulative exercises; or mixed, involving both the verbal and the concrete. Little data were found in the verbal category but the concrete mode produced a mean effect size of .75 and the mixed mode produced a mean effect size of .44.

The source of structure concept addressed the source of instructional objectives, content, and/or method used in the treatment. The categories included student self-directed, student interacting with materials/and or the teacher, the teacher as the source of structure, and criterion referenced sources. The source of structure involving student self-direction produced a very low average effect size, .04. The structure that involved interaction of the student with materials and/or the teacher produced a mean effect size of .70. A similar effect size (.69) was found for "criterion referenced," although this result is based on only two studies.

The locus of control concept addressed the approach used in meeting the objectives, etc., set forth in the structure component. The categories included student self-directed, student and teacher working together, teacher directed, and a mix of part student and part teacher directed. The student self-directed category produced a mean effect size of .81, based on 44 effect sizes. Though a higher value is reported for "teacher directed," it is based on only one study.

The training technique concept addressed educational practices usually employed within the confines of a course or workshop. This concept included the following categories: interaction analysis feedback, instructional strategy feedback, wait-time analysis, questioning analysis, micro-teaching peers, micro-teaching students, modeling strategy, and behavior coding training or strategy analysis. Instructional strategy feedback produced a mean effect size of .67; modeling strategy, 1.56; micro-teaching peers, .72; micro-teaching students, .81; behavior coding training analysis, 1.37; and questioning analysis, 1.38.

The technology concept addressed the use of audio technology, video technology, programmed material or auto-tutorial methods as treatment variables. Treatments using audio technology had a mean effect size of .99.

Summary

The data analyzed in this study tend to agree with other meta-analysis studies (Anderson, 1982) and other reviews of research (Helgeson, Blosser, and Howe, 1977). Higher effect sizes were generally obtained with (1) more specific instruction, (2) instruction that involved a substantial amount of concrete experience, and (3) instruction involving elementary school teachers.

Positive gains were made by groups in both preservice and inservice instruction, and using a variety of techniques.

These results suggest that some alternatives to more traditional instruction should be explored. They may produce equal or better gains and save resources. Studies that involved analysis of instruction (modeling, behavior analysis, and questioning analysis) tended to have the highest effect sizes. Work with elementary teachers showed substantial gains, suggesting that they probably had few inquiry skills and gained from the instruction provided.

Teacher Outcomes - by Outcome Category

Outcome criteria were classified into the following three categories: criteria related to knowledge and intellectual processes, criteria related to classroom teacher behaviors, and criteria related to affective outcomes. Information on teacher outcome effect sizes by type of outcome is found in Table VII.

In the knowledge and intellectual processes category, knowledge of science processes was by far the most commonly measured. It was measured in 33 cases and produced a mean effect size of 1.08. Other outcome variables were measured much less frequently, as shown in Table VII. The knowledge and intellectual processes category, overall, produced an average effect size of .80 based on 55 effect sizes.

The measurement of outcome variables in the teacher classroom behavior category was more varied with six different variables being measured in four or more studies. The variable inquiry strategy had a mean effect size of .89; indirect verbal behavior, .72; interpersonal behaviors, .54; questioning-level, .72; discovery strategy, .70; and questions (process directed), 1.45. The teacher classroom behavior category overall produced a mean effect size of .82 based on 60 effect sizes.

A variety of affective measures was used in these teacher education studies including measures of attitudes toward science, science teaching, and several others. The average effect size in these categories varied from .09 to .79, with a mean overall effect size for the affective category of .47 based on 31 effect sizes.

Summary

Teaching science processes appeared to be a realistic goal, effectively taught in many studies. The mean of effect size, 1.08, was the highest mean in the knowledge and intellectual processes category. While some other variables had mean effect sizes from .5 to .90, a few studies (particularly problem solving) had low effect sizes.

Teacher classroom behavior appeared to be effective in many studies. Nearly all the skills and processes that were taught had mean effect sizes of .5 to over 1.0. Questioning skills and other verbal skills had mean effect sizes from .7 to 1.45.

Affective variables appeared to be more difficult to teach or to gain large effect sizes. Most means ranged from about .34 to .7.

These results are very similar to the conclusions of the review of research by Balzer, Evans, and Blosser (1973). Cognitive (low level) and skill outcomes are usually easiest to teach. Complex behaviors and affective outcomes are usually harder to teach. The data indicate that many treatments were able to achieve respectable effect sizes emphasizing a variety of learning outcomes. Instruction with groups involving fewer students were usually more effective than for groups with larger numbers of students.

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